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Title of Grant:

Dynamics and Morphology of Superfluid Helium Drops in a Microgravity Environment

Type of Report:

Summary of Research

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Summary of Research

We have investigated experimentally two methods of simulating microgravity conditions for liquid helium on earth so as to be better able to design studies of the dynamics of superfluid helium in a microgravity environment in space. We have successfully levitated small drops of helium using the forces produced by focussed laser beams. Larger drops have been levitated in a magnetic trap produced by a superconducting magnet. In the process of studying levitated drops in a magnetic trap we observed that two drops in apparent contact often did not coalesce for several minutes.

In the experiments involving laser levitation, drops of 10 to 20 μm diameter were produced by a piezoelectric tranducer submerged just below a surface of bulk helium. The drops could be suspended for periods of minutes in the optical trap formed by two counterpropagating, horizontal, focussed beams produced by a 4 W Nd:YAG laser. The drops were observed to evaporate slowly. Calculations show that direct laser heating either by Brillouin or Raman scattering of the light in the liquid helium produces a negligible rate of evaporation of the drop. Evaporation of the drop by the enhanced vapor pressure of the curved drop surface appears to be a significant effect limiting the lifetime of the drops. An important experimental difficulty is the heating of the cell by scattered laser light. We have calculated the characteristics of the optical trap and the deformation of the liquid drops by the light forces. While we have demonstrated that laser levitation can be successfully used to levitate small helium drops, it is impractical to use the technique to levitate drops much larger than employed here. The laser power required to levitate a drop increases as the cube of the radius.

Using a large magnetic field we have stably levitated helium drops of up to 2 cm diameter at temperatures down to 1.5 K. To acheive a magnetic force on helium equal to the force of the earth's gravity requires a product of field times field gradient of 21.5 T^2cm^{-1}. A specially designed superconducting solenoid produces the required field. With the solenoidal axis vertical a stable static trap is created in which helium drops can be levitated indefinitely. Because the trap forces are not spherically symmetric, large liquid drops are substantially deformed. The relative deformation decreases with drop size, falling as the cube of the radius. We frequently observe two drops in the magnetic trap held in apparent contact for up to 3 minutes without coalescing. This non-coalescence effect is seen only above the superfluid transition temperature. We have been able to explain this effect as resulting from the existence of a vapor layer between the drops caused by evaporation. The evaporation is a consequence of non-equilibrium conditions within the experimental cell such that the drops are slowly cooling by evaporation.

Using drops levitated in the magnetic trap we are now in a position to investigate the dynamics and morphology of free superfluid helium drops. The behavior of superfluid

drops with angular momentum is expected to be different from that of rotating classical fluid drop because in a superfluid the flow must satisfy the condition $\nabla \times \vec{v} = 0$. The experience gained in working with magnetically levitated drops on earth should prove extremely beneficial in the formulation of plans for space-based measurements.

Publications:

"Morphology of Superfluid Drops with Angular Momentum", G. M. Seidel and H. J. Maris, Physica B **194-196**, 577 (1994).

"Laser Levitation of Superfluid Helium", M. A. Weilert, D. L. Whitaker, H. J. Maris and G. M. Seidel, J. Low Temp. Phys. **98**, 17 (1995).

"Magnetic Levitation of Liquid Helium", M. A. Weilert, D. L. Whitaker, H. J. Maris and G. M. Seidel, Czech. J. Phys. **46** S1 373 (1996).

"Magnetic Levitation of Liquid Helium", M. A. Weilert, D. L. Whitaker, H. J. Maris and G. M. Seidel,J. Low Temp. Phys., to be published January 1997.